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Splat!: An RF Signal Propagation, Loss and Terrain Analysis Tool

Analyze the coverage area of your local repeater or the propagation path between two stations with this multi-platform analysis tool.

SPLAT! is a powerful terrestrial signal propagation and terrain analysis tool created by KD2BD for the spectrum between 20 MHz and 20 GHz. It has many useful applications in the field of wireless electronics.

SPLAT! can accurately determine minimum antenna height requirements between transmitters and receivers to establish line-of-sight paths and Fresnel Zone clearances. *SPLAT!* can estimate path loss, field strength and received signal levels based on the Longley-Rice Irregular Terrain Model. *SPLAT!* can produce signal contour maps suitable for visualizing repeater system coverage areas, assist in designing point-to-point control links, wireless Wide Area Networks (WANs) and help perform frequency coordination and interference studies. Its capabilities and performance rival those of commercial software packages costing tens of thousands of dollars.

SPLAT! is free software designed primarily for operation on *Unix* and *Linux*-based workstations. Alternate versions for other operating systems are also available.

Recently, Dr. Bill Walker, W5GFE, has created a Web based interface allowing many of the *SPLAT!* functions to be executed through any Internet connected platform that supports a graphical Web browser.

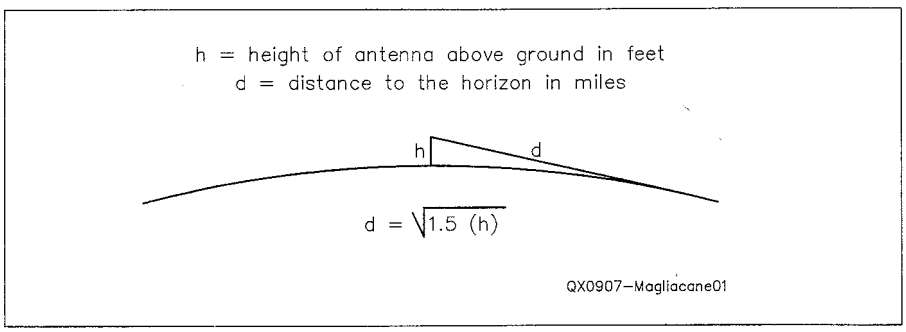

Figure 1 — Simple line of sight model over a smooth Earth.

SPLAT! History

SPLAT! was originally created in 1997 to estimate the line-of-sight operational coverage of the N2SMT/R 70 cm ATV repeater at Brookdale Community College in Lincroft, New Jersey. The program was rewritten several times before finally being released to the public via the Internet under the GNU General Public License in April 2002.

About a year after its release, Dr J. Douglas McDonald, ex-WA5HDC, integrated point-to-point Longley-Rice Irregular Terrain Model code into *SPLAT!*, which enabled accurate estimates of RF path loss to be made. Doug is co-author of several patents relating to adaptive equalization and echo cancellation techniques employed in digital television (DTV) reception, and used *SPLAT!* in some of his DTV reception studies.

In early 2005, Doug Lung, AH6DL, Vice President for Engineering at Telemundo/NBC, wrote an article for *TVTechnology* magazine discussing the use of *SPLAT!* in illustrating the coverage area of several DTV transmitting facilities. Follow-up correspondence with Doug provided valuable suggestions and technical guidance for adding support for high gain directional antenna systems employing both electrical and mechanical beam tilt used in the television broadcast industry. Doug was also able to provide "sanity checks" during code development by verifying results obtained through *SPLAT!* with those of actual ground-based measurements and of commercial software packages of similar function.

The use of *SPLAT!* reached beyond the planet in 2006 when Vaughn Cable, K6ZTA, at NASA's Jet Propulsion Laboratory in Pasadena, California obtained a copy of *SPLAT!* with the intention of modifying it for use in developing path loss and fade margin policies for communication links of interest to NASA in preparation for future manned lunar and Martian surface operations and exploration.

How It Works

Communication paths on VHF and higher frequencies take place through a variety of mechanisms such as line-of-sight propagation, diffraction over the horizon and the Earth's terrain, atmospheric refraction and various forms of scatter. The easiest of these to consider is a line-of-sight path.

Figure 1 illustrates how the distance of a line-of-sight propagation path between an antenna and the horizon can be determined. The associated equation actually takes atmospheric refraction into account, which extends the radio horizon to a distance slightly beyond that of the optical horizon.

When the height of the second antenna in

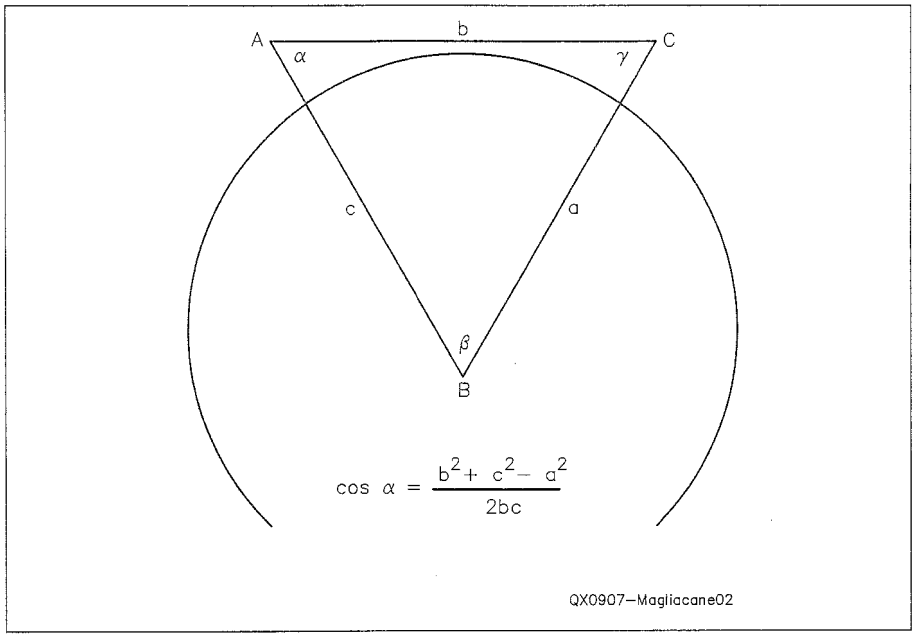

Figure 2 — Simple line of sight model with both antennas above the Earth's surface.

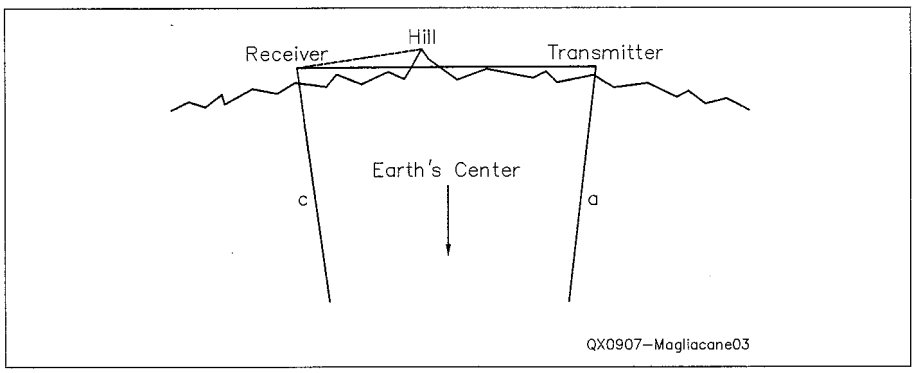

Figure 3 — Simple line of sight model over a rough Earth.

Figure 4 — A Longley-Rice Terrain Shielding Plot, 146 MHz, centered on W1AW (cropped).

the communications link extends to a known distance above the Earth's surface, the maximum length of the propagation path can be determined through simple trigonometry. Figure 2 illustrates how the Law of Cosines can be used to solve for all angles in the triangle formed between Antenna A, Antenna B and the Earth's center.

A line-of-sight path exists if the angle from Antenna A to Antenna B is greater than that of the angle between Antenna A (or B) and that of the Earth below. Increasing the Earth's radius by 33 percent over its actual amount effectively compensates for the effects of atmospheric refraction on the propagation of the signal between the two points.

Real life, however, is much more complicated. Unless we limit ourselves to communication links between isolated ships at sea, there's terrain with which we must contend. Having an accurate model of the Earth's terrain permits a determination as to whether a terrain feature will cast a shadow between the two points in question. As before, line-of-sight determination becomes a trigonometry exercise, and every terrain feature along the path between transmitter and receiver must be taken into account to qualify the path. See Figure 3.

Is Line-of-Sight Enough?

Whether a line-of-sight path is required for reliable communications depends on many variables. High power commercial VHF and UHF broadcasters will claim that a line-of-sight path to their transmitting antenna is not a necessity for adequate reception of their signals. On the other hand, a WiFi operator using low-powered unlicensed transceivers will claim that a line-of-sight path is in and of itself, insufficient information for ensuring reliable operation of their equipment. Both claims are correct. A terrestrial line-of-sight condition, in fact, provides us very little detail regarding the actual RF attenuation experienced over that path, or its long-term reliability.

The Longley-Rice Propagation Model

In the 1960s, Anita Longley and Phil Rice developed a general purpose propagation model based on electromagnetic theory and statistical analysis capable of predicting the median path loss of terrestrial radio signals propagating across irregular terrain. Their model has become the FCC's defacto standard in predicting path loss for the spectrum between 20 MHz and 20 GHz, and is heavily used in the commercial broadcast industry for predicting service contours, and performing interference studies.

Longley-Rice propagation modeling is used in Amateur Radio applications as well.

The April 2008 issue of *QST* carried an article by Dan Henderson, N1ND, describing the efforts by ARRL and concerned repeater owners to resolve a problem that has arisen concerning shared usage of the 420 MHz band by amateurs and large (and classified) USAF PAVEPAWS radars operating within close proximity to each other.

The USAF must have, and is lawfully entitled to, an interference-free environment in which to operate PAVEPAWS radars. At the same time, amateur repeater owners are interested in sharing the 420 MHz band with these radar systems when it is technically possible to do so.

Dan Henderson's article mentioned that one of the tools employed by ARRL in an attempt to resolve the conflict was "Longley-Rice terrain shielding calculations."

Longley-Rice Terrain Shielding Calculations

The FCC has long recognized Longley-Rice terrain shielding calculations as acceptable evidence when considering waivers for geographic restrictions in granting commercial broadcasting licenses.[1]

Figure 4 shows the results of a 146 MHz Longley-Rice terrain shielding calculation centered on W1AW, assuming a target antenna height of 5 feet (typical for a mobile antenna).

Until recently, such calculations have, of necessity, been the province of large mainframe computers, with substantial engineering talent available for interpreting the results. "*SPLAT!*" makes the analysis of terrain, and the determination of Longley-Rice model path-loss available to the average Amateur Radio operator.

SPLAT! has two drawbacks for the average user. The first is the fairly large number of "command line" parameters that are necessary to control the program, and the second is the rather large data sets, which describe geographic terrain data to the program so that accurate topographic maps may be created. (We comment, though, that the first "drawback" is precisely the reason why it was easy to create a Web interface to the program.)

The terrain data itself, a product of the STS-99 Space Shuttle Radar Topography Mission, is available in the public domain from several sources, and covers a large portion of the Earth. In addition, data that provides geographic locations for cities and political boundaries in the United States is available through the United States Bureau of the Census. The volume of data is intimidating, and depending on their needs, not everyone will be interested in downloading it, much less storing it.

[1]Notes appear on page 14.

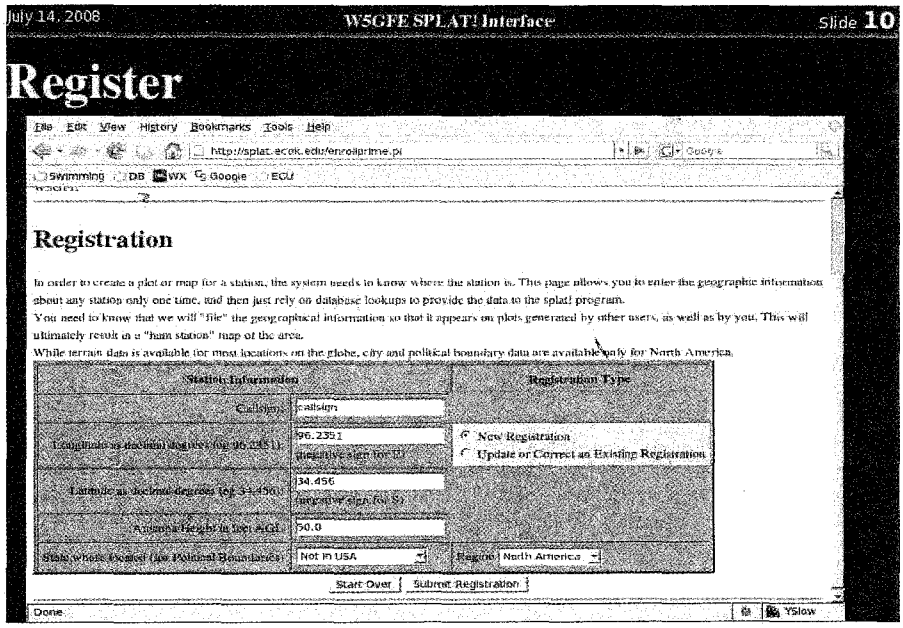

Figure 5 — This screen shot is the Registration Page from the *SPLAT!* Web site.

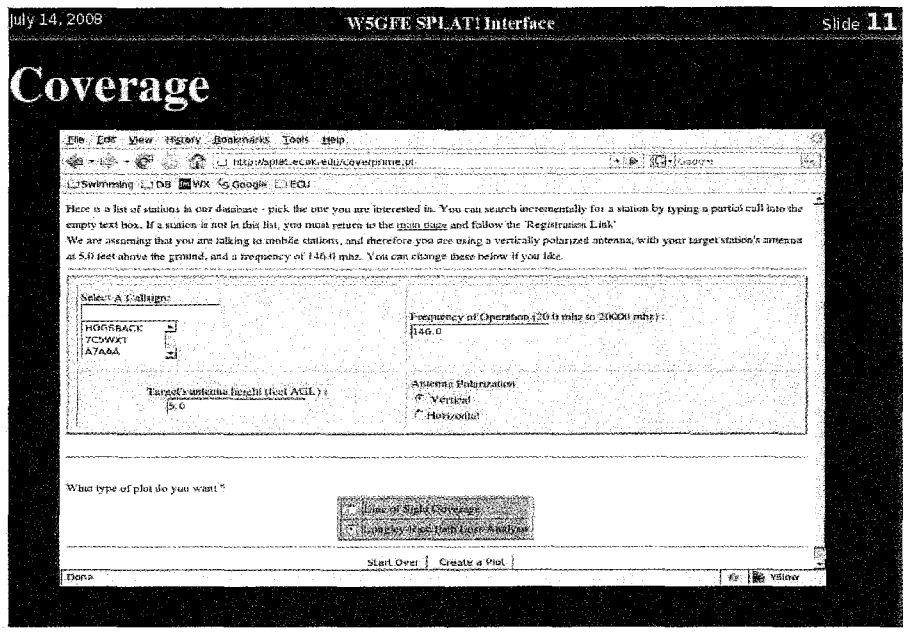

Figure 6 — Here is a screen shot of the Coverage Page from the Web site.

The *SPLAT!* Web Interface

Having access to a good-sized LAMP (*Linux*, *Apache*, *MySQL*, *Perl*) system, W5GFE created a general-use *SPLAT!* server capable of making the benefits of "*SPLAT!*" available to Amateur Radio operators worldwide.

W5GFE's system allows the big LAMP to serve as a repository for the *SPLAT!* data files.[2] It also provides the computational "heavy lifting" that *SPLAT!* demands, and presents the results to anyone with a Web browser via the Internet. The site is graciously hosted by the Computer Science Department at East Central University, in Ada, Oklahoma (see **http://cs.ecok.edu/**).

By following a series of Web menus, anyone can generate Longley-Rice plots, topographic maps, line-of-sight plots, profile plots, and multiple transmitter plots.

The resulting graphics are presented on a Web page that can be viewed at leisure, or saved for further manipulation. Note that some of the topographic maps are large, and may need a sophisticated image viewer

with a "zoom" feature for detailed inspection. Most Web browsers will present the images at a size that is convenient for direct viewing.

How to Use the *SPLAT!* Web Interface

The Web interface does not require any special browser, nor does it require any particular computer or operating system. Users will want a fairly fast Internet connection to be able to download topographic maps in reasonable time, but profile plots and text reports should be accessible even at dial-up speeds.

Registration

The first step is to visit the site at **http://splat.ecok.edu/** with your browser.

Users should first visit the "Registration" section of the site. See Figure 5. You will need to know the latitude and longitude of your station, as well as the height of your antenna. This data is stored in a database on the LAMP server, enabling other stations to see the location of your station on maps they generate.

The geographic data provided by each registrant is entered in a database. Each successive *SPLAT!* computation consults that database when displaying geographic locations. As a result, once a certain station is "registered," the location of that station will be plotted on succeeding maps. If your friend N1XXX registers, and you later create a plot for your own N1YYY station, the map you generate will show the locations of both N1YYY and N1XXX.

Eventually, a "ham map" of a given area is generated. Be advised that other users of the site will be able to discover the general location of your station, and your data is stored permanently on the site. The "state" information is used to plot the various cities and political boundaries of your location directly on topographic maps. This information may be somewhat incomplete.

If you wish to explore the effects of using antennas at different heights, just register several different stations at the same location (for example, W5GFE-1, W5GFE-2, W5GFE-3, and so on). If you accidentally register incorrect information, you can correct it on this page by using the "update" button.

After you have registered your site, you are ready to create plots.

Coverage Plots

Follow the "Coverage Plots" link from the main page (see Figure 6). You will see a page with a pull-down list of registered stations, and some fill-in-the-blank options. The blank "Select a Call Sign" box can be used to incrementally search for a station that is already registered. Just begin typing the call sign in the box. This is a feature of all of the pages that generate plots.

The resultant plot (Figure 7) is useful for graphic depictions of coverage areas.

Profile Plots

Profile plots are not very large, and can probably be handled even by a slow Internet connection. The plots are "normalized," which in this case means that the stations on each end of the circuit appear at the same level on the graph, and the various paths are traced against these "normalized" locations.

As you can see in Figure 8, the opportunity to select two stations is provided, as is the ability to create signal profiles of the terrain between those two stations. Selecting the topographic map option will create a map containing the two stations, and a line of site path between them (if it exists).

Two plots created by the "profiles" page appear in Figures 9 and 10.

Multi Station Plots

It is interesting to plot combined coverage areas of linked repeater sites by using the "Multiple Station Plots" link. The pull-

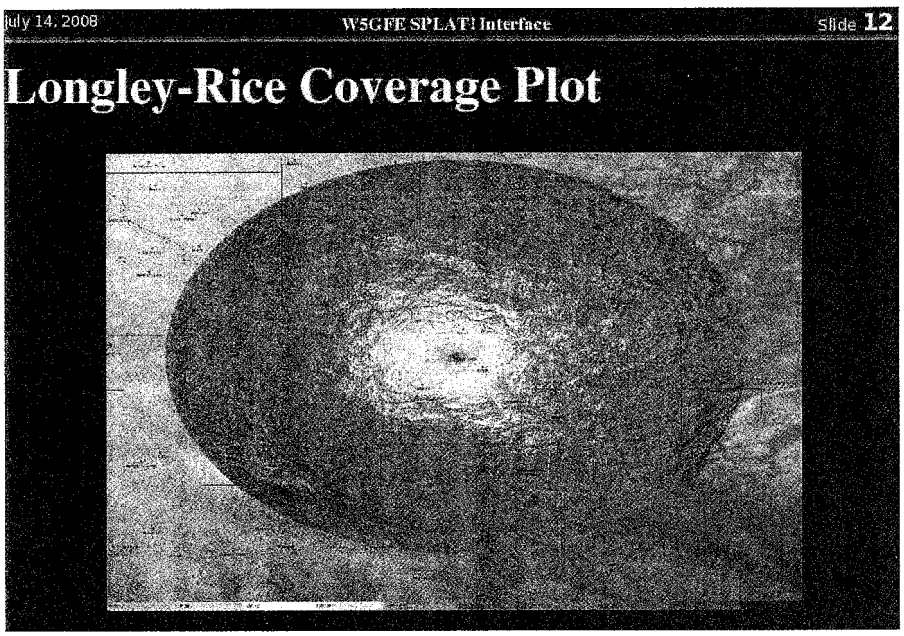

Figure 7 — This Coverage Graph shows the results after entering the station information at the Coverage Page.

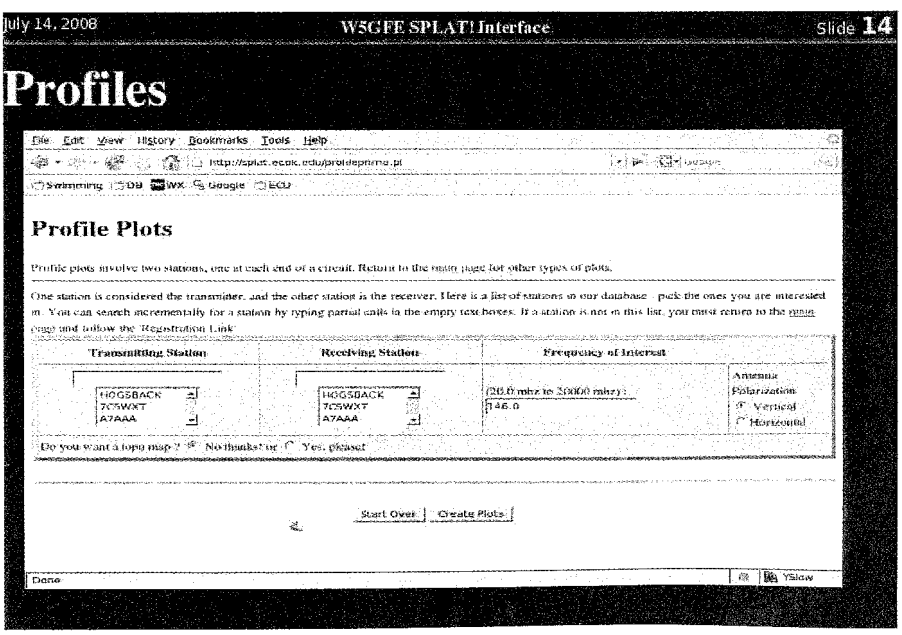

Figure 8 — Use the Profiles Page to create a profile of the path between two stations.

down menus of Figure 11 allow selection of up to four transmitting sites simultaneously. Colors are used to delineate the coverage of each transmitter and to show the combined coverage area. See Figure 12. Interestingly, two different antennas on the same tower may be treated as though they are "multiple transmitters."

Installing Your Own

Even though the command line version of *SPLAT!* is easy enough to use, the Web interface is sufficiently convenient that users may want to install it on their own equipment, especially if they are plotting a large number of stations, and want successive maps to include previously plotted stations.

The computational demands of the Web interface are not trivial, though it is certainly possible for a club to host the interface on a local Web site. The complete installation, including world wide maps, comprises about 17 GB of disk space. A "North America only" installation would run about 1.5 GB, and a "local area only" installation might take less than 250 MB.

The ability to execute CGI programs under a Web server will be required, as will the administrative authority over a database under *MYSQL*. Users will need to be able to offer "write permissions" for the Web server on at least one directory, and will need to be able to compile the *SPLAT!* source code, or download the binaries from one of the many on line repositories.

Some of the larger plots may require more time than your Web server can provide to a single connection. There is a setting in the Apache configuration that can adjust this "timeout" parameter. Documentation is available in the "HOWTO" file.

This list of requirements sounds more daunting than it actually is. Most *Linux* distributions come with all of the required applications pre-installed. The *SPLAT!* source code and the Web interface, with a "HOWTO" document is available for downloading through the W5GFE Web site at East Central University, Ada, Oklahoma: **http://splat.ecok.edu/**.

Acknowledgments and Disclaimer

Stan Horzepa, WA1LOU, kindly publicized the W5GFE *SPLAT!* Web site in his excellent on-line "Surfin'" blog on March 7, 2008. The site scored a "virtual WAS" over the subsequent weekend. You can still find that blog by going to the ARRL Web site (**www.arrl.org**) and typing SPLAT in the "Search Site" window.

Walter K1CMF pointed out an error that prevented the original Web site version (though not *SPLAT!* itself) from functioning correctly on frequencies other than 146.0 MHz. Walter also confirmed that the corrections, when made, allowed agreement with other relevant materials in his possession. Walter is directly involved with the effort to avoid interference to the PAVEPAWS system on Cape Cod, Massachusetts.

The definitive Web site for *SPLAT!* belongs to John, KD2BD, and can be found at **www.qsl.net/kd2bd/splat.html**.

John's program is a wonderful creation, and a major contribution to ham radio. Bill's Web site could not exist without John's *SPLAT!*

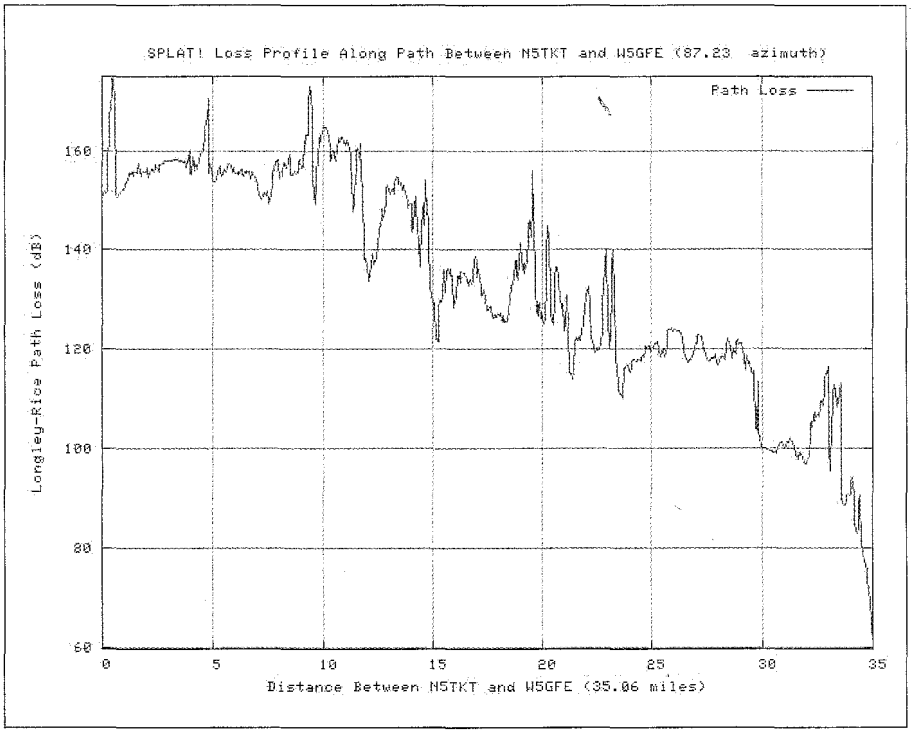

Figure 9 — This graph shows the Path loss (in dB) between two stations.

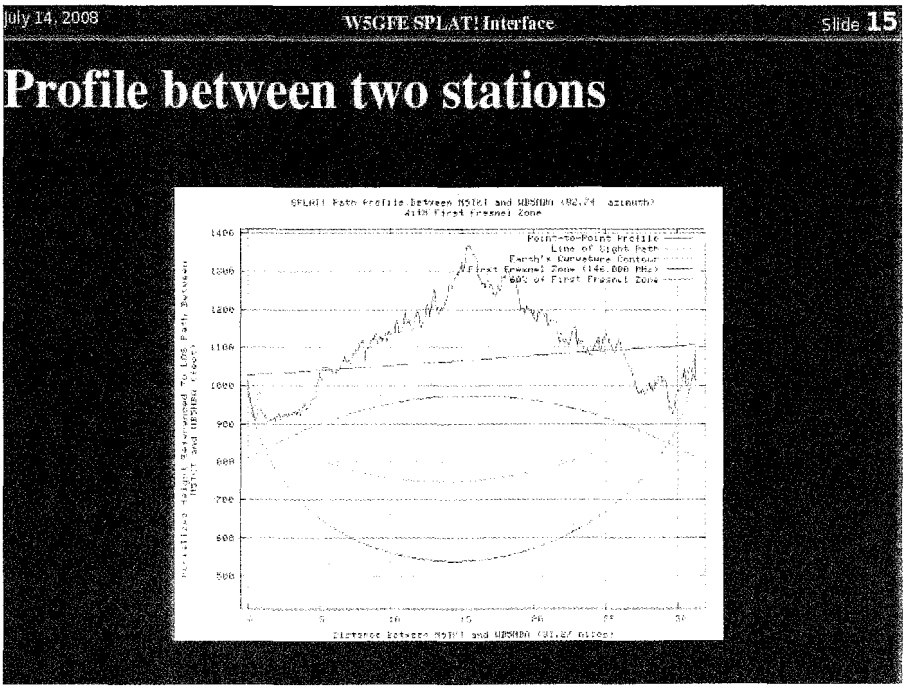

Figure 10 — Here is a screen shot of the program results for "Normalized Terrain and Path Between Two Stations."

Notes

[1]FCC Office of Engineering and Technology Bulletin No. 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference," and others, **www.fcc.gov/Bureaus/Mass Media/Public Notices/LPTV Notices/pnmm0039.doc**.

[2]Quad dual-core Opteron 64 bit processors, with 32 GB of main memory, and 1.5 TB of disk storage, running *RedHat Linux*.

John Magliacane, KD2BD, has held an Advanced class license for over 25 years, and a Commercial FCC Radio License since 1994. John holds Associate Degrees in Electronics, Computer Science and Mathematics as well as a Bachelor's Degree in Electronics Engineering Technology.

Since 1987, John has been employed as a Learning Assistant for electronics courses offered at Brookdale Community College, Lincroft, NJ and has served as advisor for the College's Amateur Radio Club since 1991. John has also worked as a freelance technical writer for about 15 years. His weekly "Space News" newsletters enjoyed great popularity across the packet radio networks during the 1990s.

John prefers the technical aspects of Amateur Radio, having engineered BPSK and FSK modems for Pacsat satellite communications, and Linux-based satellite tracking and related communications software. In recent years, John has been active in frequency measuring tests using receiving apparatus, frequency measuring methods and instrumentation of his own design.

Bill Walker, W5GFE, was first licensed as a "Conditional Class" in 1961, at the age of 14, and has held the same call sign since then. He has upgraded to Amateur Extra class. He is an ARRL Life Member.

Dr Walker received a BS in mathematics from West Texas A&M in 1968, and MS (1970) and PhD (1974) degrees in mathematics from Texas Tech. He currently is appointed Adolph Linscheid Distinguished Teaching Professor and is Chair of Computer Science at East Central University in Ada, Oklahoma. He was founding chair of the Oklahoma Computing Consortium.

Dr Walker has published in RTTY Journal, 73 Magazine, QST, QEX, Byte *and professional journals. He has authored three textbooks (all in the computing field) and presented many papers at professional meetings.*

He is a 32nd degree Mason, and although not a Native American, belongs to the Comanche Little Ponies, the Comanche War Dance Organization, and the Intertribal Singers Drum. He also serves on the editorial board for Whispering Winds magazine.

Bill has been married 29 years (to the same woman!) and lives in rural Oklahoma with his wife Anita, their son Dalton and spotted dog Leia.

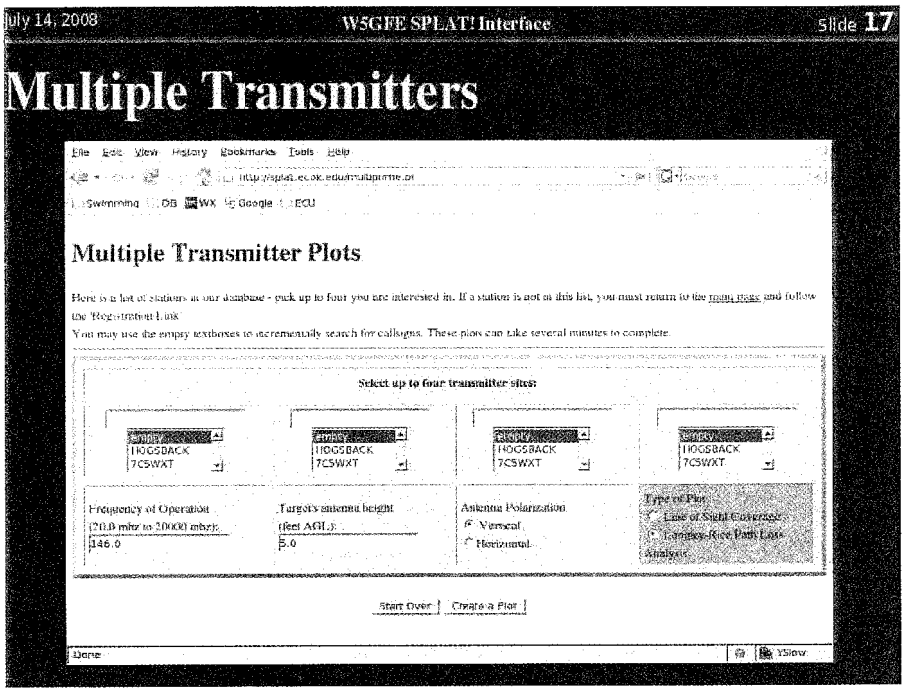

Figure 11 — You can analyze the coverage for multiple transmitters.

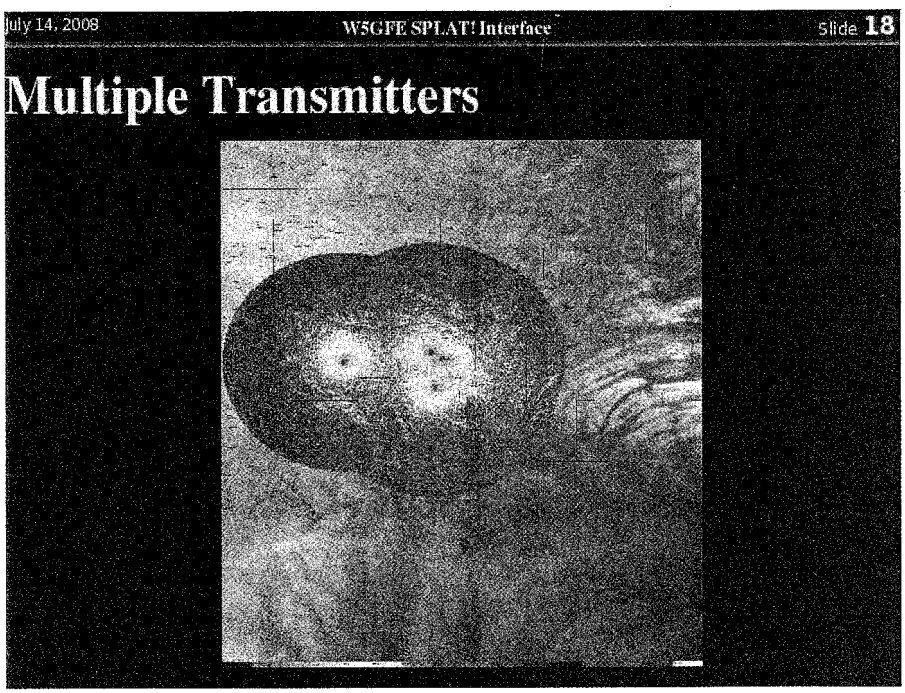

Figure 12 — Here is an example of the output plot created when you enter data for multiple transmitters.